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UNIDO

Photovoltaic System Iran

Pre-Feasibility Study

Tehran, Iran
8/1/2014

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1. Solar PV technology

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulated electrons (negative charges) in a layer in the cell designed to lose electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load (e.g., as in a light bulb).

A photovoltaic power station, also known as a solar park, is a large-scale photovoltaic system (PV) designed for the supply of merchant power into the electricity grid. Most solar parks use ground mounted (sometimes called free-field or stand-alone) arrays. They can either be fixed tilt or tracking, either single axis or dual axis. Tracking increases the output, but also the installation and maintenance cost. The DC power output of the solar arrays is converted to AC by inverters, and connection to the grid is through a high voltage three phase step up transformer, usually to 10 kV or above

1.1 Composition of a PV system

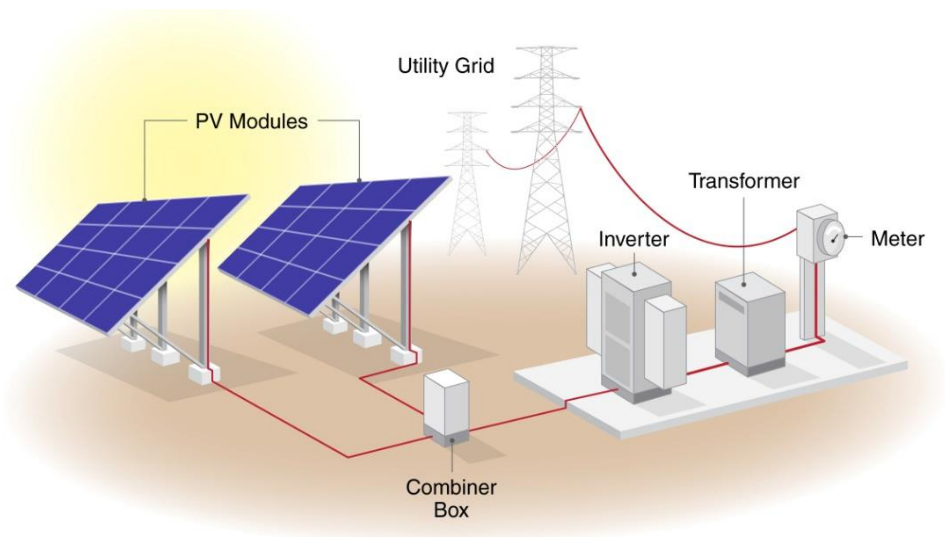


Figure 1 Composition of a PV system

A typical PV system is made up of several key components (figure 1) , including:

- PV modules, made of cells
- Inverter
- Transformer
- Balance-of-system (BOS) component

Optionally, a photovoltaic system may include any or all of the following: renewable energy credit revenue-grade meter, maximum power point tracker (MPPT), battery system and charger, GPS solar tracker, energy management software, solar concentrators, solar irradiance sensors, anemometer, or task-specific accessories designed to meet specialized requirements for a system owner.

1.1.1 Photovoltaic modules

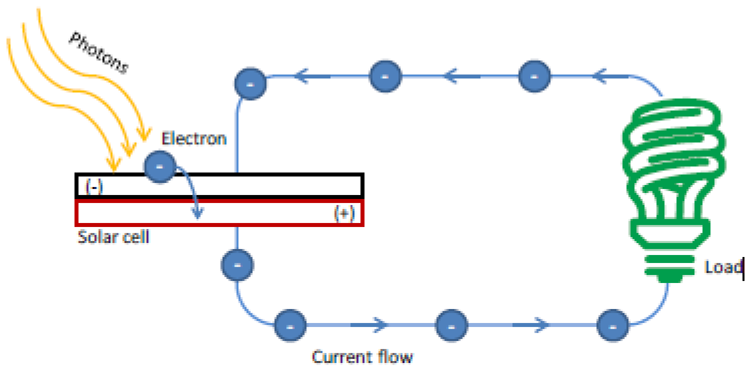


Figure 2 Generation of electricity from a PV cell (Source: EPA)

The diagram (figure 2) illustrates the operation of a basic photovoltaic cell, also called a solar cell. Solar cells are made of the same kinds of semiconductor materials, such as silicon, used in the microelectronics industry. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current -- that is, electricity.

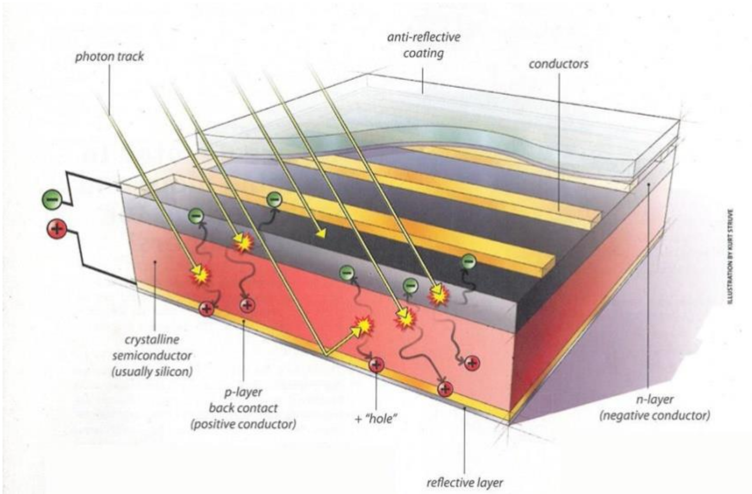
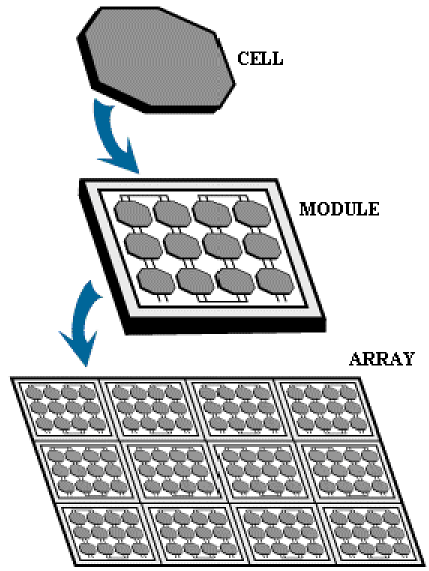


Figure 3 Outline of a PV Cell



A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module(figure 4) . Modules are designed to supply electricity at a certain voltage, such as a common 12 volts system. The current produced is directly dependent on how much light strikes the module.

Multiple modules can be wired together to form an array. In general, the larger the area of a module or array, the more electricity will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce any required voltage and current combination

Module technologies are differentiated by the type of PV material used, resulting in a range of conversion efficiencies from light energy to electrical energy. The module efficiency is a measure of the percentage of solar energy converted into electricity.

Most solar cells are currently produced from silicon, which is abundant and nontoxic. This technology has been demonstrated for a consistent and high efficiency over 30 years in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have a lifespan in the 25- to 30-year range but can keep producing energy beyond this range.

Typical overall efficiency of silicon solar panels is between 12% and 18%(Table 1). However, some manufacturers of mono-crystalline panels claim an overall efficiency nearing 20%. This range of efficiencies represents significant variation among the crystalline silicon technologies available. The technology is generally divided into mono- and multi-crystalline technologies, which indicates the presence of grain-boundaries (i.e., multiple crystals) in the cell materials, and it is controlled by raw material selection and manufacturing technique.

Type of structure	Practical efficiency (%)	Experimental efficiency (%)
single crystal	14-17	24
multi crystal	13-15	18
amorphous	5-7	13

Table 1 Efficiency range of different types of PV cell

The four general types of photovoltaic cells are**:**

- Monocrystalline silicon.
- Polycrystalline silicon (also known as multicrystal silicon).
- Amorphous silicon (abbreviated as "aSi," also known as thin film silicon)
- Multi-junction cells

1. Monocrystalline silicon photovoltaic cells

Monocrystalline silicon photovoltaic cells are the oldest form of photovoltaic cells and have the highest conversion efficiency among all commercial photovoltaic cells today, but they require thinly sliced silicon of high purity. They need energy and capital investment to produce monocrystalline silicon, which boosts its price.

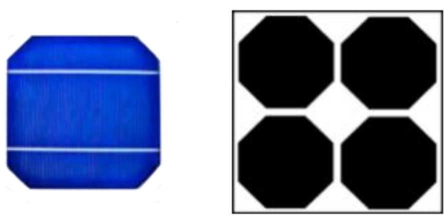


Figure 4 Monocrystalline cell

2. Polycrystalline silicon photovoltaic cells

The difference is that a lower cost silicon is used. While their heat conversion efficiency falls short of monocrystalline cells, they are inexpensive and thus are the current mainstream.

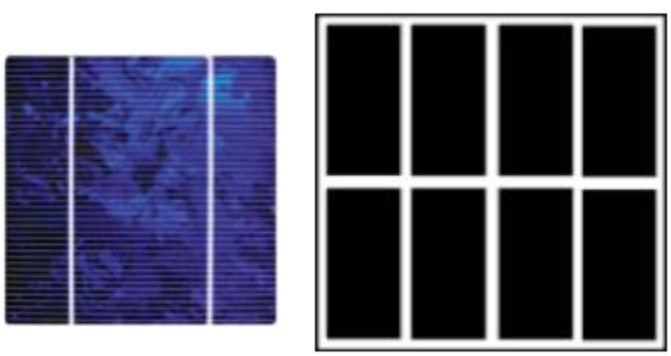


Figure 5 Polycrystalline cell

3. Thin-film silicon photovoltaic cells

These are photovoltaic cells produced by depositioning silicon film onto substrate glass. While the cost is kept low because less silicon is used compared to crystalline types, conversion is less efficient than crystalline types. But efficiency can be improved by layering several cells and generating power from each one (multijunction); something that can only be done using thin-film types. Disadvantages include higher manufacturing costs, lower efficiency, and greater corresponding space needed for energy equivalency.

Thin-film modules basically include three technological benefits when compared to crystalline modules; firstly, they use sunlight more efficiently at low levels of sun irradiation; secondly, they have lower temperature coefficients, i.e., their power output does not drop as quickly when they get hot. Thirdly, thin-film modules may be produced in a continuous manufacturing process, resulting in significant benefits in terms of manufacturing technology. The greater need for space in comparison with modules employing crystalline Si solar cells is a significant reason why thin-film solar modules in utility-scale PV play only a minor part. The efficiency of thin-film solar cells is generally less than for crystalline cells. Current overall efficiency of a thin-film panel is between 6% and 8% for a-Si and 11%–12% for CdTe.
Thin -film silicon cells can either be rigid or flexible.

- **Rigid thin-film modules**

In rigid thin film modules, the cell and the module are manufactured in the same production line. The cell is created on a glass substrate or superstrate, and the electrical connections are created *in situ*, a so-called "monolithic integration". The substrate or superstrate is laminated with an encapsulant to a front or back sheet, usually another sheet of glass. The main cell technologies in this category are CdTe, or a-Si, or a-Si+uc-Si tandem, or CIGS (or variant). Amorphous silicon has a sunlight conversion rate of 6-12%.

- **Flexible thin-film modules**

Flexible thin film cells and modules are created on the same production line by depositing the photoactive layer and other necessary layers on a flexible substrate. Flexible thin-film panels are optimal for portable applications as they are much more resistant to breakage than regular crystalline cells, but can be broken by bending them into a sharp angle. They are also much lighter per square foot than standard rigid solar panels. The global flexible and thin-film photovoltaic (PV) market, despite caution in the overall PV industry, is expected to experience a CAGR of over 35% to 2019, surpassing 32 GW according to a major new study by IntertechPira

4. Multi-junction cells

Another strategy for increasing efficiency is to use two or more layers of different materials with different band gaps. Remember that depending on the substance, photons of varying energies are absorbed. So by stacking higher band gap material on the surface to absorb high-energy photons (while allowing lower-energy photons to be absorbed by the lower band gap material beneath), much higher efficiencies can result

Smart solar modules

Several companies have begun embedding electronics into PV modules. This enables performing maximum power point tracking (MPPT) for each module individually, and the measurement of performance data for monitoring and fault detection at module level. Some of these solutions make use of power optimizers, a DC-to-DC converter technology developed to maximize the power harvest from solar photovoltaic systems. As of about 2010, such electronics can also compensate for shading effects, wherein a shadow falling across a section of a module causes the electrical output of one or more strings of cells in the module to fall to zero, but not having the output of the entire module fall to zero

Temperature coefficient

The temperature coefficient indicates the percentage by which a module's power output drops when the temperature increases. For crystalline silicon, this output is reduced by about 0.5 percent with each increase of 1 degree in temperature (°C). In thin-film modules, the value is a mere 0.25 percent. The starting point is the power output under standard test conditions at a module temperature of 25 °C

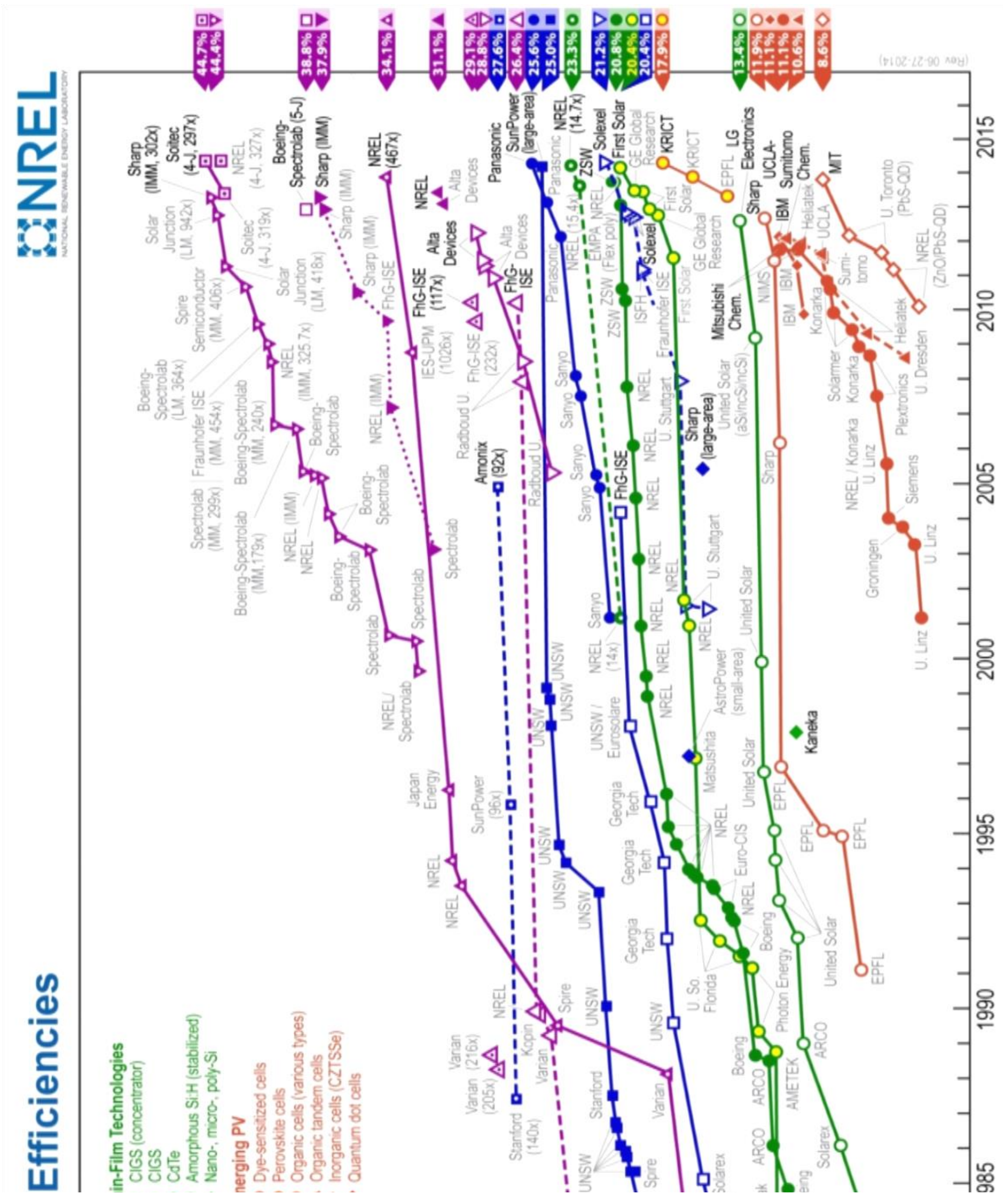


Figure 6 Best research-cell efficiencies (Source: NREL)

1.1.2 Inverter

Inverters convert DC electricity from the PV array into AC and can connect seamlessly to the electricity grid. Inverter efficiencies can be as high as 98.5%.

Inverters also sense the utility power frequency and synchronize the PV-produced power to that frequency. When utility power is not present, the inverter will stop producing AC power to prevent "islanding" or putting power into the grid while utility workers are trying to fix what they assume is a de-energized distribution system. This safety feature is built into all grid-connected inverters in the market. Electricity produced from the system may be fed to a step-up transformer to increase the voltage to match the grid.

There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weaknesses and may be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5 kW to 1,000 kW. These inverters tend to be cheaper on a capacity basis. They also have high efficiency and lower O&M costs. String inverters offer various sizes and capacities to handle a large range of voltage output. For larger systems, string inverters are combined in parallel to produce a single point of interconnection with the grid. Warranties on inverters are typically 10 years. On larger units, extended warranties up to 20 years are possible. Given that the expected life of the PV panels is 25–30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system.

Micro-inverters are dedicated to the conversion of a single PV module's power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and in limited use in larger systems due to potential increase in O&M associated with significantly increasing the number of inverters in a given array. Current micro-inverters range in size between 175 W and 380 W. These inverters can be the most expensive option per watt of capacity. Warranties range from 10–20 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. However, if micro-inverters are used, it impacts only that shaded panel and not the entire array production.

1.1.3 Balance-of-System Components

In addition to the solar modules and inverter, a solar PV system consists of BOS components, which include:

- Mounting racks and hardware for the panels
- Wiring for electrical connections.

Mounting Systems

The array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system. The selection of mounting type is dependent on many factors including installation size, electricity rates, government incentives, land constraints, latitude, and local weather. Contaminated land applications may raise additional design considerations due to site conditions, including differential settlement. election of the mounting system is also heavily dependent on anchoring or foundation selection. The mounting system design will also need to meet applicable local building code requirements with respect to snow, wind, and seismic zones. Selection of mounting types should also consider frost protection needs, especially in colder regions

Most solar parks use ground mounted (sometimes called free-field or stand-alone)arrays. They can either be fixed tilt or tracking, either single axis or dual axis. Although tracking systems are more expensive and more complex, they can be cost effective in location with a high proportion of direct irradiation. Tracking increases the output, but also the installation and maintenance cost.

a) Fixed arrays

Many projects use mounting structures where the solar modules are mounted at a fixed inclination calculated to provide the optimum annual output profile. The modules are normally oriented towards the Equator, at a tilt angle slightly less than the latitude of the site. In some cases, depending on local climatic, topographical or electricity pricing regimes, different tilt angles can be used, or the arrays might be offset from the normal East-West axis to favor morning or evening output. A variant on this design is the use of arrays, whose tilt angle can be adjusted twice or four times annually to optimize seasonal output. They also require more land area to reduce internal shading at the steeper winter tilt angle. Because the increased output is typically only a few percent, it seldom justifies the increased cost and complexity of this design.

City/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bandar Abbas(27.18, 56.27)	47.4	36.4	22.7	10.9	0.2	-4.2	-1.2	6.1	18.8	33.4	47.5	49.4
Bushehr(28.99, 50.82)	45.9	35.4	24.5	12.1	1.0	-5.3	-2.0	8.6	23.9	38.4	51.6	49.1
Zahedan(29.49, 60.86)	54.1	44	30.0	14.7	0.9	-5.2	-2.7	9.0	25.5	40.6	52.7	56.6
Shiraz(29.62, 59.53)	54.6	40.4	26.2	13.3	1.3	-5.2	-2.0	8.7	24.9	39.5	51.0	57.5
Kerman(30.29, 57.07)	52.8	42.3	27.8	14.5	1.7	-4.8	-2.0	9.8	26.6	41.7	54.6	58.6
Yasoj (30.67,51.60)	53.9	43.9	29.1	15.2	2.0	-4.5	-1.7	10.2	27.0	42.9	54.6	58.7
Ahvaz (31.33,48.69)	55.4	45.3	31.0	16.1	2.5	-4.2	-1.2	10.8	27.8	43.6	54.5	58.8
Yazd(31.9, 54.37)	56.7	47.5	32.5	16.6	2.9	-3.9	-0.9	11.3	28.2	44.0	54.7	58.8
Shahrekord (32.33,50.85)	57.2	48.1	32.7	16.9	3.5	-3.6	-0.8	11.7	28.5	44.1	55.0	59.4
Isfahan(32.63, 51.65)	54.1	42.8	29.0	14.8	4.1	-1.3	1.04	10.7	25.6	37.9	49.6	54.9
Birjand(32.87, 59.2)	58.3	47.6	33.2	17.2	3.8	-2.8	-0.1	12.2	28.9	43.6	55.9	60.9
Khoramabad(33.49,48.35)	54.7	45.1	30.2	16.2	3.6	-2.5	0.7	12.1	26.8	39.8	54.1	58.9
Ilam(33.64,46.42)	53.9	44.8	29.3	15.2	4.5	-2.8	1.4	11.9	26.1	36.5	53.9	57.5
Arak (34.09,49.69)	50.5	43.7	27.4	14.9	5.0	-0.3	2.3	11.3	24.4	37.9	50.8	54.3
Kermanshah(34.35, 47.01)	52.6	41.0	26.1	14.2	5.4	0.0	2.6	11.8	25.0	38.2	51.0	56.4
Ghom(34.64,50.88)	56.5	47.2	28.5	15.8	5.5	-0.4	2.7	12.9	27.3	40.2	55.0	57.9
Hamedan(34.87,48.51)	58.3	51.7	33.1	17.1	5.8	-0.7	2.3	13.8	30.9	42.9	57.5	60.1
Sanandaj (35.31,47.00)	58.0	49.5	32.9	17.5	5.1	-1.1	1.5	12.9	29.7	43.6	56.4	60.0
Semnan(35.58,53.39)	57.6	47.8	33.0	17.8	4.6	-1.9	0.8	12.6	28.8	44.3	55.9	60.1
Tehran(35.69, 51.42)	60.7	52.7	38.0	21.0	6.8	-0.8	2.6	15.6	32.4	48.2	60.5	63.3
Karaj(35.8, 50.97)	59.0	49.3	32.8	17.9	6.6	0.5	3.3	14.4	31.2	44.4	60.7	63.3
Qazvin(36.26,50.00)	58.9	47.1	30.1	16.6	6.4	0.8	3.5	14.1	30.7	44.1	58.5	61.2
Mashhad(36.3, 59.6)	58.3	44.7	26.3	15.6	6.7	1.2	3.7	14.2	30.5	43.1	55.8	59.2
Sari (36.56,53.06)	57.7	44.4	27.0	15.2	6.6	1.3	4.1	13.8	29.7	41.1	52.8	57.5
Zanjan(36.68,4848)	56.2	44.0	27.4	15.4	6.9	1.6	4.2	13.6	27.6	39.9	51.3	54.1
Gorgan (36.84,54.44)	58.7	47.8	29.1	16.4	7.3	1.9	4.5	13.7	28.1	40.7	54.1	60.1
Ramsar (37.28,49.59)	58.5	43.5	24.1	13.8	6.5	3.6	4.9	9.7	20.2	34.2	58.5	63.2
Bojnord(37.47, 57.33)	62.2	49.9	31.4	18.5	7.7	2.1	4.7	15.1	30.6	47.4	60.8	64.4
Urmia (37.55,45.08)	59.8	49.1	30.4	17.7	7.9	2.0	4.8	14.5	28.3	40.9	56.9	63.0
Tabriz (37.07,46.28)	35.2	37.0	24.9	14.6	7.7	2.2	5.1	14.8	29.2	41.7	53.1	46.7
Ardabil(38.25,48.30)	34.1	36.2	23.5	13.9	7.5	2.3	5.2	13.9	28.4	40.1	52.0	44.6

Table 2 The values of the slope angle at different months of a year for different cities

Source: S. A. Keshavarz, P. Talebizadeh, S. Adalatia, M. A. Mehrabian, M. Abdolzadeh, "Optimal Slope-Angles to Determine Maximum SolarEnergy Gain for Solar Collectors Used in Iran", INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH, 2012,

b) Dual axis trackers

To maximize the intensity of incoming direct radiation, solar panels should be orientated normal to the sun's rays. To achieve this, arrays can be designed using two-axis trackers, capable of tracking the sun in its daily orbit across the sky, and as its elevation changes throughout the year.

These arrays need to be spaced out to reduce inter-shading as the sun moves and the array orientations change, so need more land area. They also require more complex mechanisms to maintain the array surface at the required angle. The increased output can be of the order of 30%in locations with high levels of direct radiation, but the increase is lower in temperate climates or those with more significant diffuse radiation, due to overcast conditions. For this reason, dual axis trackers are most commonly used in subtropical regions.

c) Single axis trackers

A third approach achieves some of the output benefits of tracking, with a lesser penalty in terms of land area, capital and operating cost. This involves tracking the sun in one dimension - in its daily journey across the sky - but not adjusting for the seasons. The angle of the axis is normally horizontal, though some, which have a 20° tilt, incline the axis towards the equator in a north-south orientation - effectively a hybrid between tracking and fixed tilt. Single axis tracking systems are aligned along axes roughly North-South. Some use linkages between rows so that the same actuator can adjust the angle of several rows at once.

Wiring for Electrical Connections

In most traditional applications, wiring from the arrays to inverters and inverters to point of interconnection is generally run as direct burial through trenches. In landfill applications, this wiring may be required to run through above-ground conduit due to restrictions with cap penetration or other concerns. Therefore, developers should consider noting any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, it is recommended that PV system vendors reflect these costs in the quote when costing out the overall system.

1.2 PV System Monitoring

Monitoring PV systems can be essential for reliable functioning and maximum yield of a system. For more sophisticated monitoring and control purposes, environmental data such as module temperature, ambient temperature, solar radiation, and wind speed can be collected. Remote control and monitoring can be performed by various remote connections. Systems can send alerts and status messages to the control center or user. Data can be stored in the inverter's memory or in external data loggers for further system analysis. Collection of this basic information is standard for solar systems and it is not unique to landfill applications.

Weather stations are typically installed in large-scale systems. Weather data such as solar radiation and temperature can be used to predict energy production, enabling comparison of the target and actual system output and performance and identification of under-performing arrays. Operators may also use this data to identify, for example, required maintenance, shade on panels, and accumulating dirt on panels. Monitoring system data can also be used for outreach and education.

1.3 Operation and Maintenance

The PV panels typically have a 25-year performance warranty. The inverters, which come standard with a 5-year or 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually.

2. Siting in Iran

Selecting a suitable site is a crucial part of developing a viable solar PV project. In selecting a site, the aim is to maximize output and minimize cost. The main constraints that need to be assessed include:

- Solar resource
- Local climate
- Available area
- Land use
- Topography
- Geotechnical
- Geopolitical
- Accessibility
- Grid connection
- Module soiling
- Water availability
- Financial incentives

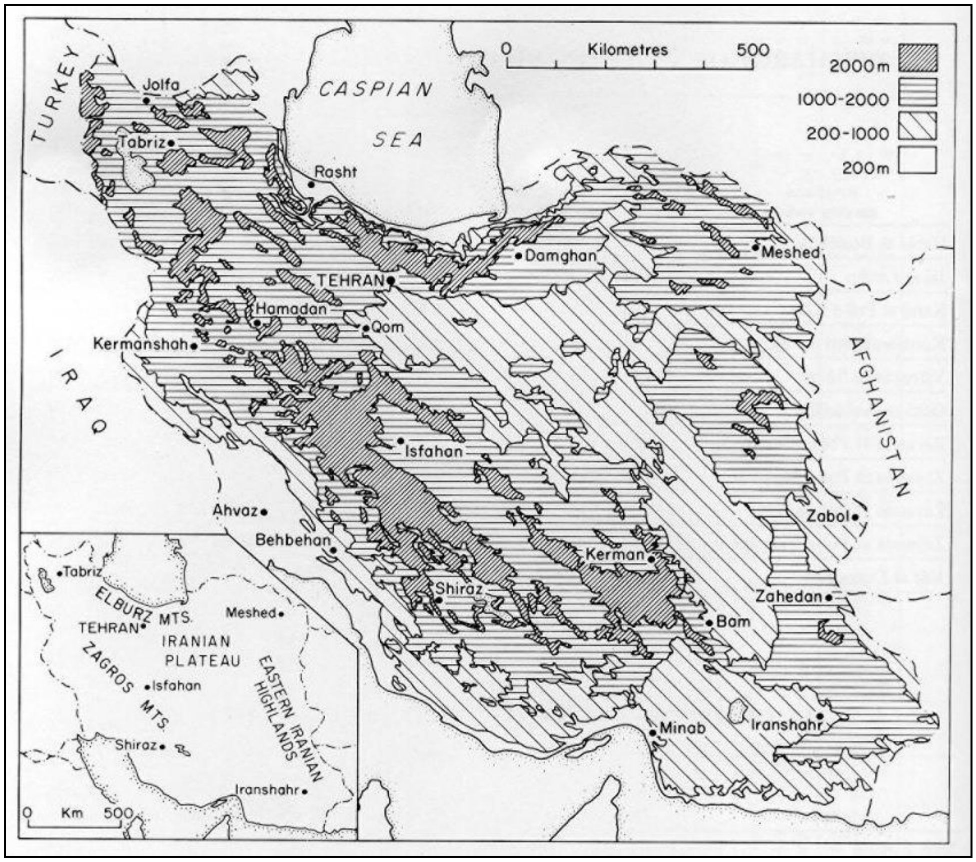
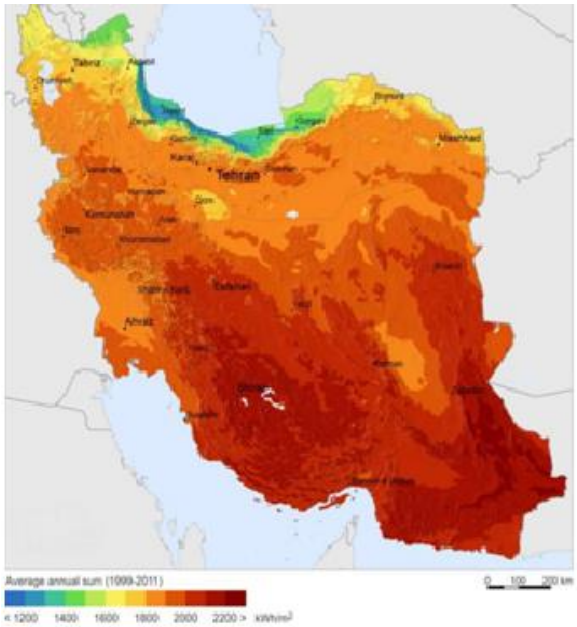


Figure 7 Major topographical features of Iran
Source: Encyclopaedia Iranica

Solar energy in the equatorial region up to the 40˚ north and south latitudes is suitable for producing electricity. Considering the large areal extent of Iran and its geographical position (between 25˚ and 40˚ N), setting up of solar power plants in many region is feasible.

The average solar energy reception of the country is 5 kWh/m^2/day or 1.825kWh/m^2/year. Thus the total annual solar energy reception of the country amounts 3x10^{15} kwh/year (figure 8) , which is about 100 times the total oil and gas reserves of the country. (Mansour Ghorbani, *The Economic Geology of Iran, 2013)*



Source: HosseinShahinzadeh, Mohammad MoienNajafAbadi, Mohammad Hajahmadi, Ali Paknejad , "*Technical And Economic Study For Use The Photovoltaic Systems For Electricity Supply In Isfahan Museum Park*", INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 2, ISSUE 1, JANUARY 2013

Figure 8 Map of the average of the received solar energy in Iran

A. Azadeh , S.F. Ghaderi, A. Maghsoudi, used a integrated hierarchical data envelopment analysis (DEA) and principal components analysis (PCA) approach to find the optimum location inter the cities in Iran for an utility scale solar power plant. Generally, solar radiation alone as a primary tool is used for determining the optimum locations for power plants. Therefore using this approach some local and social considerations are ignored. Some criteria such as population of the region, geological and geographical

DMUs	Input—intensity of natural disasters occurrence	Output			
		Solar global radiation	Quantity of proper geological areas	Quantity of availability of the water	Quantity of proper topographical areas
Abadan	19.4	441.1	36,490.3	26,590.4	691.1
Ahvaz	19.4	438.8	36,490.3	26,590.4	691.1
Bandar abbas	14.9	464	55,862.6	27,841.3	2854
Birjand	20.4	447.4	226,316.2	510,033.7	80,892
Boushehr	8.7	458.6	15,747.9	9328.7	891.2
Esfahan	8.3	452.7	80,296.3	46,706.5	10,484.1
Hamedan	3	408	14,928.7	9573.7	274.5
Karaj	5.6	431.9	27,784.6	15,574.7	2898.4
Kashan	8.3	391.4	80,296.3	46,706.5	10,484.1
Kerman	12.9	450.4	153,426.3	59,714.6	3154.4
Kermanshah	3.2	420.9	16,738.3	10,734.6	1745.7
Khoramabad	5.1	427.4	17,827	12,443.7	1378.9
Khoy	8.9	377.6	24,081.1	14,382.4	1755.2
Mashhad	20.4	415.3	226,316.2	510,033.7	80,892
Oroumiye	8.9	399	24,081.1	14,382.4	1755.2
Rasht	7.7	292.6	10,655.8	8111.7	280.3
Sabzevar	20.4	417.9	226,316.2	510,033.7	80,892
Shahrekord	3.7	441.9	11,281	10,457.2	6.5
Shiraz	24.3	479.7	83,693.9	64,323.9	5725.9
Tabriz	7.8	399.8	31,271	18,406.7	1797.3
Tehran	5.6	431.5	27,784.6	15,574.7	2898.4
Yazd	3.6	451.7	56,358.9	105,881.5	11,761.9
Zabol	7.6	452.1	154,642.3	66,001.6	10,857.5
Zahedan	7.6	443.3	154,642.3	66,001.6	10,857.5
Zanjan	1.8	364.3	18,064.1	9126.4	1560.9

considerations, and involved costs of facilities are the examples of these misunderstandings. The DEA approach uses a number of predefined parameters used to identify optimum locations of solar power plants in a country, region, etc. The results of the analysis (table 3) outlined the cities in Iran with the most adequate parameters for a PV plant : Birjand, Mashhad, Sabzevar, Zabol, Zahedan, Kerman and Yazd. *(Azadeh, A., S. F. Ghaderi, and A. Maghsoudi. "Location optimization of solar plants by an integrated hierarchical DEA PCA approach." Energy Policy 36.10 (2008))*

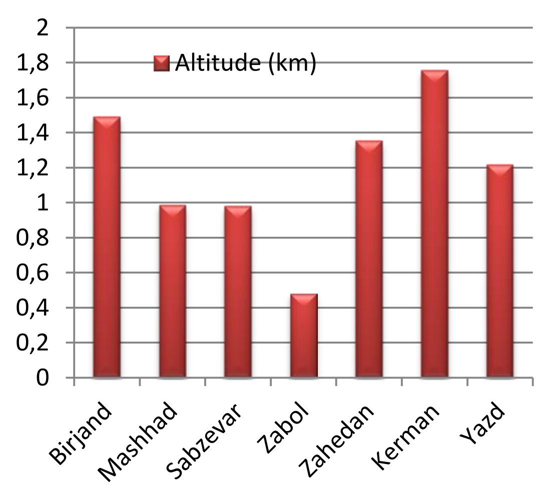
Table 3 The values of input and output parameters (indicators) for different cities

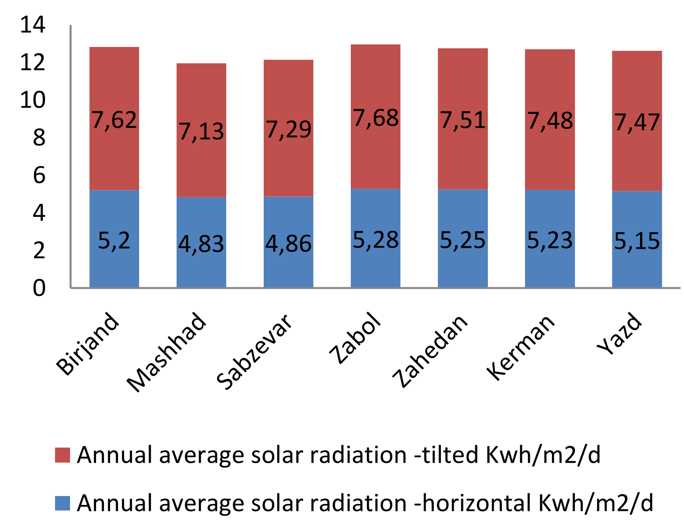
The results of the study were cross-referenced and confirmed with the following data obtained from NASA, through the RET Screen software.

The two main factors considered in the analysis, in order to identify the optimal location fo a PV power plant in Iran, where the annual average solar radiation (kwh/m2/d), both horizontal and tilted, and the altitude. In fact, thin air and low humidity at high altitude reflect and absorb less solar radiation than at sea level. The photovoltaic system can capitalize on this high intensity of sunlight hitting the ground and can booster his efficiency with colder weather.

The analysis show that the cities better suited for a PV plants, all located in the south-east provinces of Iran (figure9) ,due to an extreme exposition to horizontal solar radiation and a considerable altitude(table 4, 5,6,7), had a capacity factor for a two-axis PV around 27%, considerably higher the average factor. This factor, usually expressed as percentage, is the ratio of the actual output over a period of a year to theoretical output if the plant had operated at nominal power for the entire year. The capacity factor of a fixed tilted PV plant in southern Spain will typically be in the region of 16%. (ifc)

Figure 9 Suitable provinces for PV power plants in Iran





City	Annual average solar radiation- horizontal (Kwh/m2/d)	Annual average solar radiation- tilted(Kwh/m2/d)	Altitude (m)
Birjand	5.2	7.62	1491
Mashhad	4.83	7.13	985
Sabzevar	4.86	7.29	977,6
Zabol	5.28	7.68	480
Zahedan	5.25	7.51	1352
Kerman	5.23	7.48	1755
Yazd	5.15	7.45	1216

Table 5 Horizontal and diffuse solar radiation in selected cities and altitude

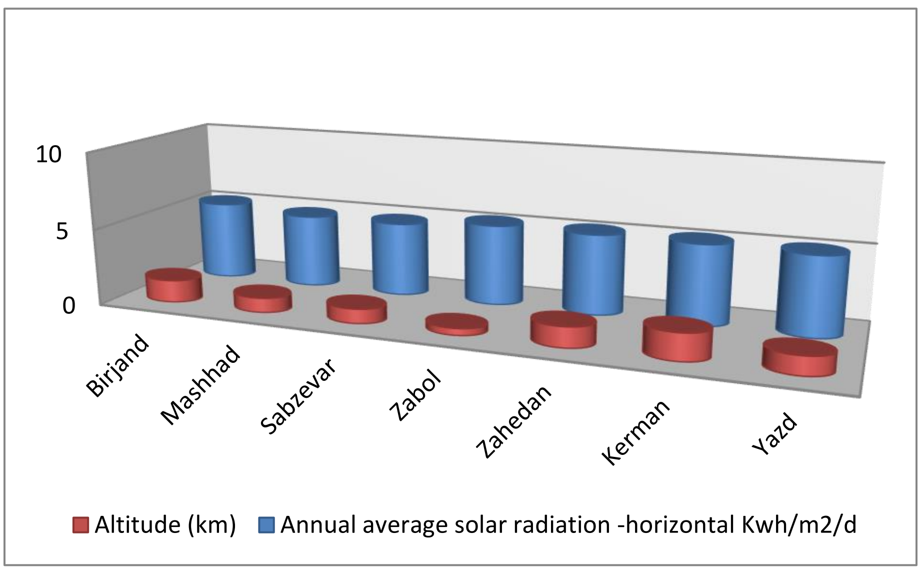


Table 6 Solar radiation and altitude for selected location in Iran

Site reference and Climate Data for Iranian cities

2.1 Birjand. South Khorasan Province

Birjand is the east Iranian provincial capital of South Khorasan at 32°52′N latitude and 59°12′E longitude, situated at 1,491m above sea level. It has an estimated population of 157,848 inhabitants. Birjand has a cold desert climate with humidity between 20% and 50%. Its air temperature ranges between 4°C and 27°C with an annual average horizontal radiation of 1.90 MWh/m^2

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	25.0	27.0	32.0	36.0	40.0	43.0	44.0	42.0	39.2	36.0	29.0	25.0	44
Average high °C	11.0	13.1	18.8	24.7	30.6	35.2	35.6	34.3	31.7	26.6	19.7	13.4	24.6
Daily mean °C	4.0	6.2	11.7	17.6	23.3	27.9	28.8	26.8	23.1	17.5	10.8	5.8	16.96
Average low °C	−2.3	−0.3	4.4	9.6	13.9	17.9	19.7	17.1	12.1	7.3	2.2	−1.2	8.4
Record low °C	−16.5	−14.7	−12	−4.5	0.0	7.0	10.2	6.6	1.0	−5.6	−11	−15.8	−16.5
Precipitation mm	31.3	32.4	35.1	31.6	7.1	0.3	0.1	0.2	0.0	2.6	8.4	19.7	168.8
Avg. rainy days	7.9	8.3	9.2	8.0	3.6	0.7	0.4	0.2	0.3	1.6	3.3	6.3	49.8
Mean monthly sunshine hours	196.3	188.3	211.4	231.8	303.4	334.8	347.2	349.3	298.2	286.0	229.6	195.8	3,172.1

Table 7 Climate data for Birjand (Source: NOAA 1961–1990)

The following data for Birjand were obtained from NASA, through the RET Screen software tool.

	Unit	Climate data location	Project location		
Latitude	˚N	32.9	32.9		
Longitude	˚E	59.2	59.2		
Elevation	m	1,491	1,491		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation – horizontal**	**Earth temperature**
		°C	%	kWh/m²/d	°C
January		4.3	58.1%	2.75	3.8
February		6.4	49.6%	3.56	6.4
March		11.6	43.6%	4.47	12.7
April		17.1	34.8%	5.56	21.3
May		22.2	25.3%	6.78	27.7
June		26.5	20.2%	7.64	31.7
July		27.7	21.9%	7.72	32.7
August		25.7	20.0%	7.08	30.5
September		21.9	20.3%	6.14	25.6
October		17.0	27.8%	4.72	18.9
November		10.9	37.4%	3.25	12.5
December		6.1	52.2%	2.67	6.1
Annual		16.5	34.2%	5.20	19.2
Measured at	m				0.0

Table 8 Site reference and climate data for Birjand

2.2 Mashhad. Razavi Khorasan Province

Mashhad is a town located in the north east of Iran at 36°18′N latitude and 59°36′E longitude and 985 m altitude. It is the capital of Razavi Khorasan province. It has an estimated population of 2,772,287 inhabitants, making it the second largest city in Iran after Teheran. The city is located in the valley of the Kashaf River near Turkmenistan, between the two mountain ranges of Binalood and Hezar-masjed. The city benefits from the proximity of the mountains, having cool winters, pleasant springs, mild summers, and temperate autumns. Mashhad features a steppe climate hot summers and cool winters with humidity between 30% and 70%. The city only sees about 250 mm of precipitation per year, some of which occasionally falls in the form of snow. Mashhad also has wetter and drier periods with the bulk of the annual precipitation falling between the months of December and May. Summers are typically hot and dry, with high temperatures sometimes exceeding 35 °C. Winters are typically cool to cold and somewhat damper, with overnight lows routinely dropping below freezing. Mashhad enjoys on average just under 2900 hours of sunshine per year with an annual average horizontal radiation of 1.76 MWh/m².

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	24	26	32	35.4	39.2	41.6	43.8	42.4	42	35.8	29.4	28.2	43.8
Average high °C	7.2	9.2	13.9	20.8	26.6	32.2	34.4	33	28.9	22.3	15.4	9.7	21.1
Average low °C	−3.8	−2.1	2.6	8.2	12.2	16.2	18.5	16.2	11.5	6.1	1.7	−1.9	7.1
Record low °C	−27	−28	−13	−7	−1	4	10	5	−1	−8	−16	−25	−28
Precipitation mm	33	35.2	55.6	46.3	27.6	4.2	1.1	0.8	1.7	8.6	15.4	24.7	254.2
Mean monthly sunshine hours	149.1	147.3	161.2	198.6	279.2	341.7	366.1	358.7	304.5	247.4	187.5	151.1	2,892.4

Table 9 Climate data for Mashhad (Source NOAA 1961-1990)

	Unit	Climate data location	Project location		
Latitude	˚N	36.3	36.3		
Longitude	˚E	59.6	59.6		
Elevation	m	999	999		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	kWh/m²/d	°C
January		0.8	72.3%	2.33	1.5
February		2.9	67.8%	3.03	3.1
March		8.2	65.7%	3.58	8.7
April		14.4	57.4%	4.92	17.8
May		19.3	45.7%	6.50	24.8
June		24.0	34.7%	7.81	30.0
July		26.1	32.9%	7.64	31.8
August		24.0	30.6%	7.14	29.2
September		19.6	36.1%	5.72	24.0
October		13.7	45.6%	4.11	16.6
November		8.6	63.0%	2.86	9.6
December		3.4	71.6%	2.17	3.5
Annual		13.8	51.9%	4.83	16.8
Measured at	m				0.0

Table 10 Site reference and Climate data – Mashhad (RazaviKhorazan)

2.3 Sabzevar . Razavi Khorasan

Sabzevar is a city in, and the capital of Sabzevar County, in Razavi Khorasan Province in northeastern Iran. At the 2006 census, its population was 208,172, in 57,024 families. It is locate at 36°12′45″N longitude and 57°40′55″E latitude. It has annual average sunshine hours of 2850 with an annual average horizontal radiation of 1.77 MWh/m². It is located at 977.6 m above sea level. The prevailing climate in Sabzevar is known as a local steppe climate. Throughout the year there is little rainfall in Sabzevar. The average annual temperature in Sabzevar is 16.1 °C. The average annual rainfall is 169 mm.

	Unit	**Climate data location**	**Project location**		
Latitude	˚N	36.2	36.2		
Longitude	˚E	57.7	57.7		
Elevation	m	978	978		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	kWh/m²/d	°C
January		4.1	62.1%	2.72	0.5
February		7.0	54.0%	3.65	2.4
March		11.3	50.6%	4.54	8.0
April		18.1	41.9%	5.56	17.1
May		23.4	34.2%	6.52	24.3
June		28.9	26.2%	7.17	29.8
July		31.0	24.4%	6.89	32.1
August		29.8	22.5%	6.37	29.9
September		25.0	26.2%	5.39	24.9
October		18.6	34.9%	4.07	16.8
November		11.5	47.6%	2.96	9.1
December		6.0	61.4%	2.43	2.7
Annual		17.9	40.4%	4.86	16.5
Measured at	m				0.0

Table 11 Site reference and climate data- Sabzevar(Razavi Khorasan)

2.4 Zabol. Sistan and Baluchestan province

Zabol is a city in and the capital of Zabol County, Sistan and Baluchestan Province, located at 31°01′43″N latitude and 61°30′04″E longitude and 480 m altitude in the south-east part of Iran. Zabol lies on the border with Afghanistan, but also close to the border with Pakistan. Referred to as Sistan until the late 1920s, the city was renamed Zabol by Reza Shah Pahlavi.[2]At the 2006 census, its population was 130,642, in 27,867 familiesZabol has a hot desert climate with an annual average sunshine hours of 3180. Over the course of a year, the temperature typically varies from 33°F to 110°F and is rarely below25°F or above 113°F with a range of humidity of 13 % and 58%.Its annual average horizontal solar radiation is 1.93 MWh/m². Zabol area is well known for its "120 day wind" (*bād-e sad-o-bist-roz*), a highly persistent dust storm in the summer which blows from north to south.

	Unit	**Climate data location**	**Project location**		
Latitude	˚N	31.0	31.0		
Longitude	˚E	61.5	61.5		
Elevation	m	510	510		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	kWh/m²/d	°C
January		6.7	59.4%	3.33	7.7
February		9.1	50.6%	4.26	10.6
March		14.8	42.4%	4.93	17.1
April		22.4	26.1%	5.96	25.8
May		27.9	17.7%	6.70	31.8
June		32.4	13.4%	7.21	35.9
July		34.0	15.7%	6.90	37.7
August		32.2	16.3%	6.68	35.6
September		27.4	15.9%	5.93	30.2
October		20.8	22.6%	4.80	22.8
November		15.0	31.8%	3.61	16.3
December		9.2	49.4%	2.97	10.1
Annual		21.0	30.0%	5.28	23.5
Measured at	m				0.0

Table 12 Site reference and climate data- Zabol (Sistan and Baluchestan)

2.5 Zahedan. Sistan and Baluchestan

Zahedan is a city in and the capital of Sistan and Baluchestan Province, Iran. At the 2006 census, its population was 552,706, in 109,488 families. Zahedan is located at 29°29′47″N latitude and 60°51′46″E longitude, near Pakistan and Afghanistan, only about 41 km (25 mi) south of the tripoint of the borders of the three countries, at an altitude of 1,352 m (4,436 ft) above sea level. Zahedan has a hot desert climate with hot summers and cool winters. Precipitation is very low, and mostly falls in winter with a range of humidity between 14% and 47%. It has an average of monthly sunshine hours of 3,169.7 and annual average horizontal solar radiation of 1.92 MWh/m^2.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	27.0	28.0	32.2	37.0	40.4	43.0	42.0	43.0	40.0	36.0	30.2	28.0	43
Average high °C	14.0	16.5	21.9	27.5	32.5	36.2	37.0	35.6	32.3	27.7	21.7	16.3	26.6
Daily mean °C	6.4	9.2	14.5	20.0	24.7	28.3	29.3	27.1	22.7	17.8	11.9	7.9	18.32
Average low °C	−0.5	2.5	7.4	12.1	15.9	18.6	19.8	17.2	12.4	8.1	3.1	0.5	9.8
Precipitation mm	19.3	21.1	13.6	9.5	3.9	0.4	0.8	0.9	0.2	1.8	3.4	7.2	82.1
Avg. rainy days	4.3	4.5	4.2	4.2	2.4	0.3	0.4	0.2	0.3	0.9	1.3	2.8	25.8
Mean monthly sunshine hours	208.8	199.3	221.2	235.2	296.2	310.2	317.9	324.5	305.4	290.2	245.6	215.2	3,169.7

Table 13 Climate data for Zahedan (Source: NOAA 1961-1990)

	Unit	Climate data location	Project location		
Latitude	˚N	29.5	29.5		
Longitude	˚E	60.9	60.9		
Elevation	m	1,370	1,370		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	kWh/m²/d	°C
January		6.8	46.3%	2.97	8.3
February		9.5	40.3%	3.86	11.1
March		14.7	34.1%	4.67	17.3
April		19.8	24.9%	5.58	25.3
May		24.2	19.8%	6.69	31.0
June		27.4	15.4%	7.25	34.6
July		28.4	17.6%	7.25	35.8
August		26.4	14.7%	6.97	33.5
September		22.3	16.9%	6.11	28.7
October		17.9	25.1%	4.89	22.3
November		12.4	32.8%	3.69	16.2
December		8.4	43.1%	3.00	10.4
Annual		18.2	27.5%	5.25	22.9
Measured at	m				0.0

Table 14 Site reference and climate data- Zahedan(Sistan and Baluchestan)

2.6 Kerman. Kerman Province

Kerman is the capital city of Kerman Province, located at 30°17′N latitude and 57°05′E longitude. At the 2011 census, its population was 821,374, in 221,389 households, making it the 10th most populous city of Iran. It is the largest and most developed city in the Kerman Province and the most important city in South-East Iran. It is one of the largest cities of Iran in terms of area. It is located on a large, flat plain, 1,036 km (643 mi) south of Tehran at 1755 m above sea level.

The city's many districts are surrounded by mountains which bring variety to Kerman's year round weather pattern, thus the northern part of the city is located in an arid desert area, while the highland of the southern part of the city enjoys a more moderate climate. The mean elevation of the city is about 1755 m above sea level. Kerman city has a moderate climate and the average annual rainfall is 135 mm. Because it is located close to the Kavir-e lut, Kerman has hot summers and in the spring it often has violent sand storms. Otherwise, its climate is relatively cool. It has monthly average sunshine hours of 25o and an annual of around 3000. Its average annual horizontal solar radiation is 1.91 MWh/m^2

	Unit	Climate data location	Project location		
Latitude	˚N	30.3	30.3		
Longitude	˚E	57.0	57.0		
Elevation	m	1,754	1,754		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	$kWh/m^2/d$	°C
January		4.8	51.3%	2.94	5.2
February		8.0	41.3%	3.86	7.9
March		12.2	35.4%	4.78	13.0
April		17.9	30.2%	5.44	21.1
May		22.7	22.8%	6.72	27.3
June		27.1	17.6%	7.42	31.5
July		28.8	19.4%	7.28	32.8
August		26.3	18.7%	6.94	30.7
September		23.2	19.5%	6.00	26.1
October		17.6	25.4%	4.75	20.0
November		10.6	35.3%	3.61	13.2
December		6.4	47.7%	2.89	7.2
Annual		17.2	30.3%	5.23	19.7
Measured at	m				0.0

Table 15 Site reference and climate data – Kerman (Kerman province)

2.7 Yazd. Yazd province

Yazd is the capital of Yazd Province. The city is located at 31°53′50″N latitude and 54°22′04″E longitude at 1,216 m above sea level. At the 2006 census, the population was 423,006, in 114,716 families.

Yazd is the driest major city in Iran, with an average annual rainfall of only 60 millimeters, and also the hottest north of the Persian Gulf coast, with summer temperatures very frequently above 40 °C in blazing sunshine with no humidity. Its annual average hours of sunshine are 3,129.1with an annual average horizontal solar radiation of 1.88 MWh/m^2.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	27.0	28.0	32.0	37.0	41.0	44.0	45.0	45.6	42.0	36.0	30.0	27.4	45.6

Average high °C	12.2	14.8	19.5	21.9	33.4	36.3	39.5	36.1	35.3	26.5	19.3	17.0	26.0
Daily mean °C	5.1	8.0	13.5	19.5	25.4	30.8	32.4	30.4	26.1	19.5	12.1	6.8	19.13
Average low °C	−0.8	0.1	5.3	9.5	17.7	20.0	23.3	19.9	18.7	8.6	2.3	−0.7	10.3
Avg. precipitation days	1	3	2	11	1	1	1	0	1	0	2	0	23
Mean monthly sunshine hours	181.6	203.0	207.5	230.9	293.9	334.1	340.7	335.0	313.1	278.1	217.8	193.4	3,129.1

Table 16 Climate data for Yazd (Source: NOAA)

	Unit	Climate data location	Project location		
Latitude	˚N	31.9	31.9		
Longitude	˚E	54.4	54.4		
Elevation	m	1,230	1,230		
Month		**Air temperature**	**Relative humidity**	**Daily solar radiation - horizontal**	**Earth temperature**
		°C	%	$kWh/m^2/d$	°C
January		5.5	53.0%	2.78	4.1
February		8.2	46.0%	3.75	6.6
March		13.4	37.0%	4.61	11.6
April		19.0	33.0%	5.39	19.6
May		24.7	25.0%	6.53	26.0
June		29.8	18.0%	7.19	31.2
July		31.5	17.0%	7.33	32.9
August		29.5	18.0%	7.17	30.9
September		25.4	19.0%	6.11	25.9
October		19.1	27.0%	4.83	19.3
November		12.2	38.0%	3.39	11.9
December		7.1	47.0%	2.69	6.1
Annual		18.8	31.4%	5.15	18.9
Measured at	m				0.0

Table 17 : Site references and climate data- Yazd (Yazd province)

3. Policy

The Ministry of Energy of Iran, guarantees the purchase of the renewable energy produced by the private sector for 5 year at a Feed In Tariff (FIT) and after this period for 15 more years based on power stock market and including price of fuel.(?) For the calculation the cost/watt for the production of electricity with a gas power plant of 0,08€/watt was used as a reference for the period of time after the FIT.
The Feed in Tariff consists in a base rate of 4800,00 IRR/KW (0.13611€/KW), to be paid in IRR, with an annual increase of around the 10 % considering the inflation and the exchange rate.
The Feed in Tariff might be extended to 8 years in future.

The SUNA (Iran Renewable Energies Organization) is the governmental company coordinating the projects in charge of the development of applications related to renewable energies. SUNA will help the developers in gathering all the approvals.
The only stockholder of SUNA is Tavanir (a holding company in production and transfer and dispatch of electricity) however, SUNA performs it's tasks under the supervision of Deputy of Electricity Affairs.

3.1 Implementing the project in terms of policies (steps)

1) Registration in SUNA
2) Submitting Feasibility Study by developer & approving the FS report in an overall view by SUNA
3) Gathering Approvals or Permissions including:

- Grid Connection Permission from TAVANIR,
- Environmental Permission from the Conservation of Environment Organization of Iran,
- Land Use Permission from the governmental lands authorization,
- Final Establishment Approval from MOE;
- Signing Power Purchase Agreement with TAVANIR (SUNA will prepare the drafts & necessary documents together with the investor),
- Construction of the power plant by the developer. SUNA will monitor and generally supervise the activities,
- Beginning of Operation of the Power Plant. SUNA will coordinate the grid connection tests & inspections via TAVANIR & Grid Management Company of Iran.

3.2 Registration procedure

- Foreign investors can either register a new company by themselves in Iran or start a joint venture with existing Iranian companies to establish a power plant.
- It is suppose that corporation with an Iranian consultant company in regard to the site selection, achieving the required permissions (connecting to the grid, environment and possessing the land) would be very helpful and facilitator.
- The project will begin by introducing the site of power plant and project company to SUNA.

3.3 Foreign Investment Promotion and Protection Act (FIPPA)

The law protecting foreign investment in Iran is the Foreign Investment Promotion and Protection Act ratified in 2002 which is referred to as FIPPA.

The scope of applicability of the FIPPA extends to the territory of the Islamic Republic of Iran under which all foreign investors may invest in the Country and enjoy the privileges available there under, a FIPPA allows investors to invest with greater confidence.

3.4 Taxation in Iran

A new flat rate corporation tax of 25 per cent payable on the profits of corporate commercial entities has been introduced. Taxation in Iran generates particular unease among foreign firms because they appear to be arbitrarily enforced – tax bills are initially based on 'assumed earnings' calculated by the Finance and Economy Ministry according to the size of the company and the sector in which it operates. Factors such as the quality and location of a company's offices are also widely believed to have an impact on tax assessment.

All foreign investors doing business in Iran or deriving income from sources in Iran are subject to taxation. Depending on the type of activity the foreign investor is engaged in, various taxes and exemptions are applicable, including profit tax, income tax, property tax, etc.

Generally speaking, Iran has two types of laws concerning foreign companies. The first are laws that address issues concerning foreign companies directly such as the *Foreign Investment Promotion and Protection Act* (FIPPA) and the second are general laws of which certain articles or by-laws address foreign companies, for instance the Taxation Law and the Labor Law. The Tax Act had divided the source of income earned by foreign companies either direct or through their branches in Iran into three main categories:[25]

- Income earned in Iran by way of contracting operations
- Income earned from Iran by way of royalties and licensing fees
- Other activities - trading operations, etc.

[Note: *The Amendment* has introduced certain changes in the tax treatment of the above activities.]

Foreign legal entities must pay taxes on all taxable income earned through investments in mainland Iran or from direct or indirect (through agents, branch offices, etc.) activities in mainland Iran, at the flat rate of 25% as mentioned in Article 47 of *the Amendment* law

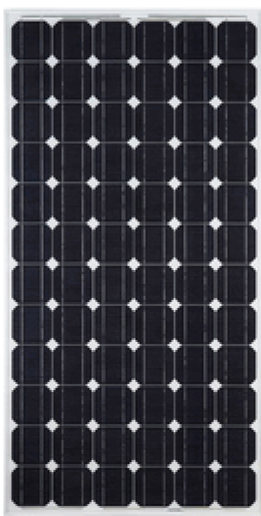
4. Analysis

The analysis considered a central-grid solar energy farm of 1000 MW from Suntech. The solar module that was used for the calculation is Suntech's high-efficiency photovoltaic module STP180S-24/Ad, using silicon substrate monocrystalline cell, from a large single crystal (figure)mounted on a dual axis tracking system. Based on the product information obtained and the experience from similar projects elsewhere from RETScreen, the following characteristics were used for the assessment of the solar resource.

4.1. PV Modules

According to the information from Suntech, a brand new STP180S-24/Ad solar module has the following technical specifications.

Suntech STP180S-24/Ad 180Watts 24V Monocrystalline Panel
Manufacturer Model: Suntech STP180S-24/Ad



Features

- High conversion efficiency
- High power tolerance (±3%)
- Withstands high wind-pressure and snow load (passed IEC 5400Pa mechanical loading test), and extreme temperature variations

Excellent transferable warranty

- 5 years for materials and workmanship
- 12 years for 90% peak power outputs
- 25 years for 80% peak power outputs

Quality and Safety

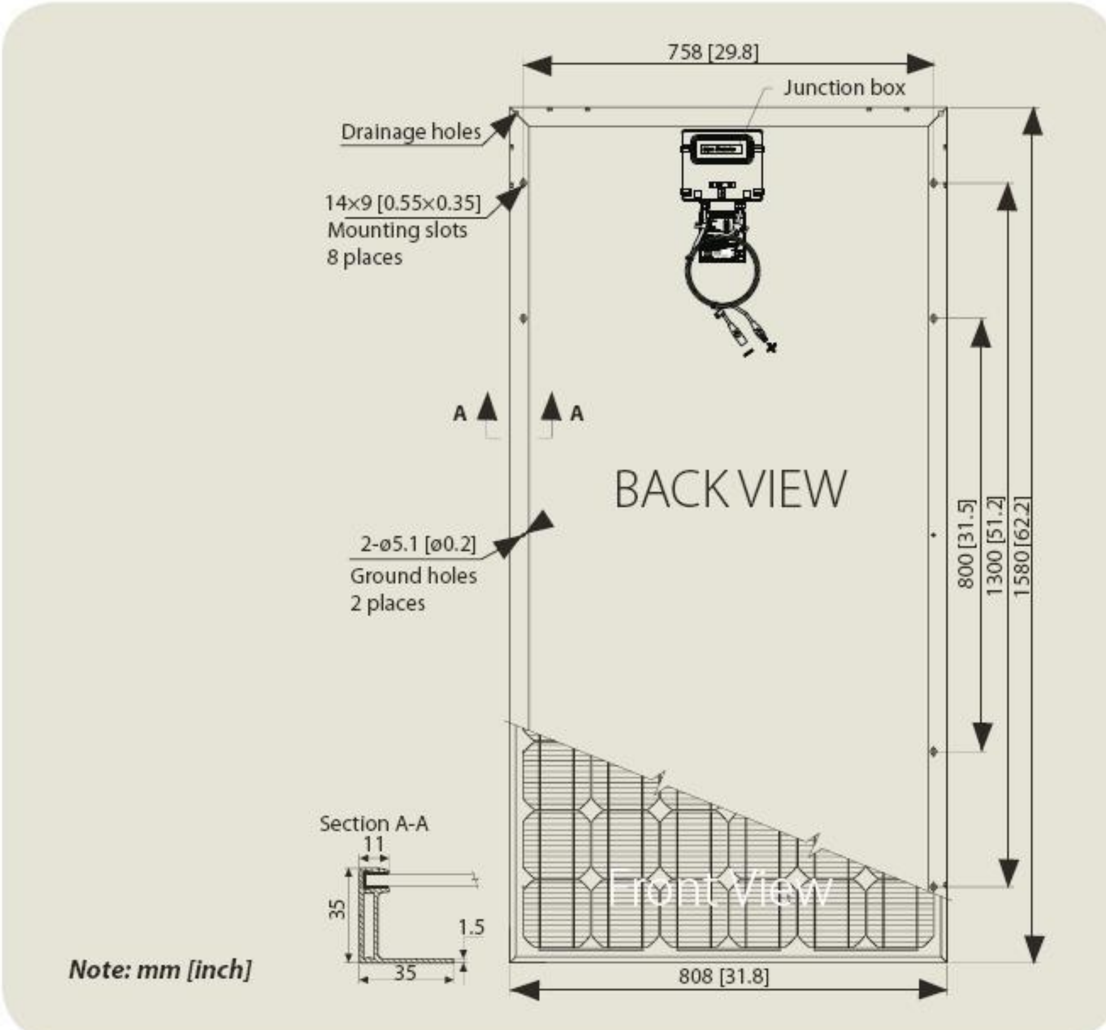
- 25-year power output transferable warranty
- High quality standards with optical, mechanical and electrical component testing during and post-production
- ISO 9001:2000 (Quality Management System) and ISO 14001 (Environmental Management System) certified factories manufacturing world class products
- IEC61215, IEC61730 by the TUV Rheinland Group.

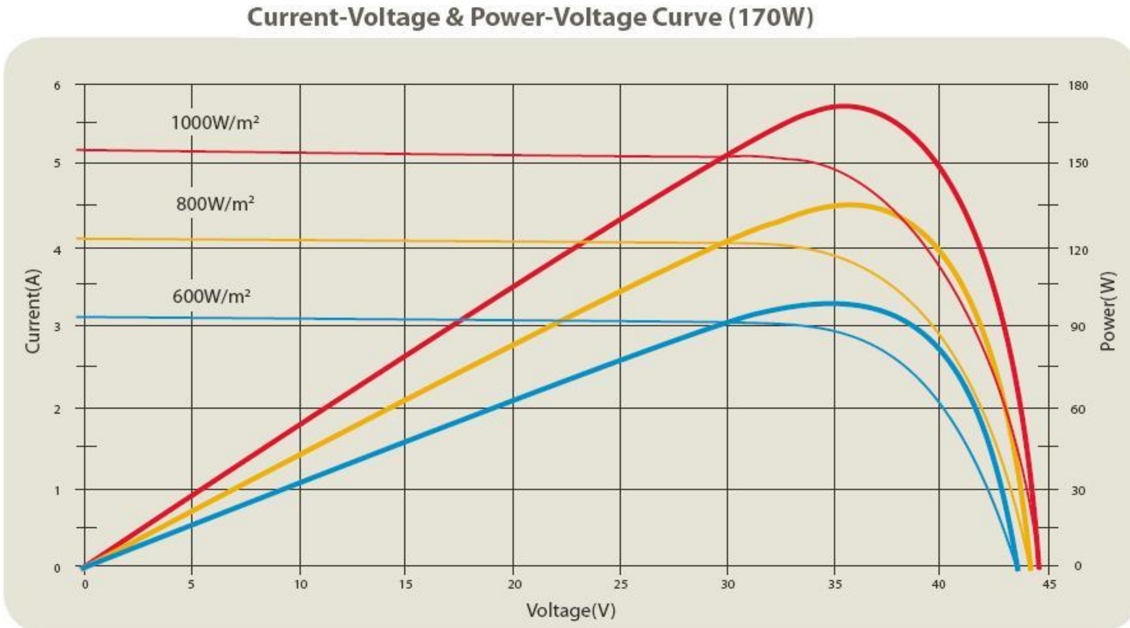
Specification

Electrical Characteristics	
Open - Circuit Voltage (Voc)	44.4V
Optimum Operating Voltage (Vmp)	35.6V
Short - Circuit Current (Isc)	5.40A
Optimum Operating Current (Imp)	5.05A
Maximum Power at STC (Pmax)	180Wp
Operating Temperature	-40ºC to +85ºC
Maximum System Voltage	1000V DC
Maximum Series Fuse Rating	10A
Power Tolerance	±3 %
STC: lrradiance 1000W/m2, Module temperature 25ºC, AM=1.5	

Temperature Coefficients	
Nominal Operating Cell Temperature (NOCT)	45ºC±2ºC
Temperature Coefficiency of Pmax	-0.48 %/ºC
Temperature Coefficiency of Voc	-0.34 %/ºC
Temperature Coefficiency of Isc	0.037 %/ºC

Mechanical Characteristics	
Solar Cell	Mono-crystalline 125×125mm (5inch)
No. of Cells	72 (6×12)
Dimensions	1580×808×35mm (62.2×31.8×1.4inch)
Weight	15.5kg (34.1lbs.)
Front Glass	3.2 mm (0.13inch) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP65 rated
Output Cables	H+S RADOX® SMART cable 4.0mm2 (0.006inch2), symmetrical lengths (-) 1000mm (39.4inch) and (+) 1000mm (39.4inch), RADOX® SOLAR integrated twist locking connectors
Packing	26 Panels per Carton
Size of Carton	
Loading Capacity(20 ft Container)	
Loading Capacity(40 ft Container)	28 cartons


758 [29.8]
Junction box
Drainage holes
14×9 [0.55×0.35]
Mounting slots
8 places
A
A
BACK VIEW
2-ø5.1 [ø0.2]
Ground holes
2 places
800 [31.5]
1300 [51.2]
1580 [62.2]
Section A-A
11
35
1.5
35
Front View
808 [31.8]
Note: mm [inch]



Efficiency

Solar cell efficiency is the ratio of the electrical output of a solar cell to the incident energy in the form of sunlight. The energy conversion efficiency (η) of a solar cell is the percentage of the solar energy to which the cell is exposed that is converted into electrical energy. This is calculated by dividing a cell's power output (in watts) at its maximum power point (P_m) by the input light (E, in W/m^2) and the surface area of the solar cell (A_c in m^2).

$$\eta = \frac{Pm}{ExA_c}$$

Solar cell efficiencies vary from 6% for amorphous silicon-based solar cells to 44.0% with multiple-junction production cells and 44.4% with multiple dies assembled into a hybrid package. Solar cell energy conversion efficiencies for commercially available *multicrystalline Si* solar cells are around 14-19%. The PV cells used in the analysis have an efficiency of 14.1%, an average performance according to the current state of art.

Given a capacity per unit of 180 W, 5,555,556 units were used in the analysis in order to obtain a PV farm with an overall power capacity of 10.000.000 kW, or 1000 MW. The land use to install the two-axis tracking solar system is 7,112,376m^2

Capacity factor

The capacity factor of a PV power plant is the ratio of the actual output over a period of one year and its output if it had operated at nominal power the entire year, as described by the formula.

CF= (Energy generated per annum (kWh))/(8760(hours / annum)×Installed Capacity (kWp))

The capacity factor for a tracking system in Birjand, Iran, calculated for the analysis was 27,6%, greater than the average of 19% for a PV plant in Arizona *(Laumer, John (June 2008). "Solar Versus Wind Power: Which Has The Most Stable Power Output?". Treehugger. Retrieved 2008-10-16.)*

Resources assessment

Given the Suntech STP180S-24/Ad monocrystalline PV modules mounted on a tracking two-axis system, a monthly assessment was conducted for each of the selected cities in Iran in order to calculate the monthly and annual electricity exported to the grid, leading to different but promising results. The analysis was conducted using climate data from NASA and the characteristics of the cells, through the RET Screen software tool.

Birjand

Table : Monthly assessment results- Birjand (South Khorasan)

Month	**Daily solar radiation – horizontal**	**Daily solar radiation - tilted**	**Electricity exported to grid**
	$kWh/m^2/d$	$kWh/m^2/d$	MWh
January	2.75	4.91	142,180
February	3.56	5.34	138,261
March	4.47	6.26	175,426
April	5.56	7.11	188,090
May	6.78	8.97	238,282
June	7.64	10.16	254,641
July	7.72	10.47	269,100
August	7.08	10.07	261,379
September	6.14	9.00	229,795
October	4.72	7.99	216,223
November	3.25	5.85	158,531
December	2.67	5.14	147,490
Annual	5.20	7.62	2,419,397
Annual solar radiation – horizontal	**MWh/m^2**	1.90	
Annual solar radiation – tilted	**MWh/m^2**	2.78	

Mashhad

Table: Monthly assessment results- Mashhad (Razavi Khorestan)

Month	Daily solar radiation – horizontal	Daily solar radiation - tilted	Electricity exported to grid
	kWh/m²/d	kWh/m²/d	MWh
January	2.33	4.38	128,894
February	3.03	4.78	126,052
March	3.58	4.80	137,815
April	4.92	6.20	166,830
May	6.50	8.55	230,547
June	7.81	10.46	264,876
July	7.64	10.36	268,519
August	7.14	10.38	270,987
September	5.72	8.51	220,176
October	4.11	7.07	194,918
November	2.86	5.49	150,415
December	2.17	4.37	127,199
Annual	**4.83**	**7.13**	**2,287,230**
Annual solar radiation – horizontal	MWh/m²	1.76	
Annual solar radiation – tilted	MWh/m²	2.60	

Sabzevar

Table: Monthly assessment results- Sabzevar (Razavi Khorasan)

Month	Daily solar radiation - horizontal	Daily solar radiation - tilted	Electricity exported to grid
	kWh/m²/d	kWh/m²/d	MWh
January	2.72	5.55	159,822
February	3.65	6.24	160,164
March	4.54	6.73	188,265
April	5.56	7.27	191,294
May	6.52	8.58	227,345
June	7.17	9.35	233,175
July	6.89	9.04	230,938
August	6.37	8.86	227,388
September	5.39	7.83	198,703
October	4.07	6.96	188,000
November	2.96	5.77	155,867
December	2.43	5.21	149,149
Annual	**4.86**	**7.29**	**2,310,112**

Annual solar radiation - horizontal	MWh/m²	1.77	
Annual solar radiation - tilted	MWh/m²	2.66	

Zabol

Table: Monthly assessment results – Zabol(Sistan and Baluchestan)

Month	**Daily solar radiation – horizontal**	**Daily solar radiation - tilted**	**Electricity exported to grid**
	kWh/m²/d	**kWh/m²/d**	**MWh**
January	3.33	6.10	173,479
February	4.26	6.60	167,418
March	4.93	6.99	192,569
April	5.96	7.70	198,323
May	6.70	8.81	228,396
June	7.21	9.42	231,011
July	6.90	9.02	227,227
August	6.68	9.22	233,570
September	5.93	8.40	210,188
October	4.80	7.86	209,364
November	3.61	6.41	170,219
December	2.97	5.60	158,089
Annual	**5.28**	**7.68**	**2,399,851**
Annual solar radiation - horizontal	MWh/m²	**1.93**	
Annual solar radiation- tilted	MWh/m²	**2.80**	

Zahedan

Table: Monthly assessment- Zahedan(Sistan and Baluchestan)

Month	**Daily solar radiation – horizontal**	**Daily solar radiation - tilted**	**Electricity exported to grid**
	kWh/m²/d	**kWh/m²/d**	**MWh**
January	2.97	4.90	140,545
February	3.86	5.96	152,283
March	4.67	6.36	176,095
April	5.58	7.01	183,558
May	6.69	8.78	231,330
June	7.25	9.51	238,188
July	7.25	9.63	247,822
August	6.97	9.72	251,986
September	6.11	8.61	220,128
October	4.89	7.82	210,982
November	3.69	6.31	169,576
December	3.00	5.36	152,207
Annual	**5.25**	**7.51**	**2,374,701**

Annual solar radiation - horizontal	MWh/m²	1.92	
Annual solar radiation – tilted	MWh/m²	2.74	

Kerman

Table : Monthly assessment results- Kerman (Kerman province)

Month	Daily solar radiation – horizontal	Daily solar radiation - tilted	Electricity exported to grid
	kWh/m²/d	**kWh/m²/d**	**MWh**
January	2.94	4.95	143,039
February	3.86	5.65	145,028
March	4.78	6.63	185,133
April	5.44	6.82	180,021
May	6.72	8.83	234,314
June	7.42	9.79	245,266
July	7.28	9.68	248,616
August	6.94	9.69	251,340
September	6.00	8.47	215,765
October	4.75	7.61	205,950
November	3.61	6.26	169,494
December	2.89	5.22	149,490
Annual	**5.23**	**7.48**	**2,373,456**
Annual solar radiation - horizontal	MWh/m²	1.91	
Annual solar radiation – tilted	MWh/m²	2.73	

Yazd

Table: Monthly assessment results- Yazd (Yazd province)

Month	Daily solar radiation – horizontal	Daily solar radiation - tilted	Electricity exported to grid
	kWh/m²/d	**kWh/m²/d**	**MWh**
January	2.78	4.82	138,938
February	3.75	5.62	144,210
March	4.61	6.45	179,176
April	5.39	6.79	178,622
May	6.53	8.52	224,525
June	7.19	9.38	232,826
July	7.33	9.77	247,760
August	7.17	10.20	260,158
September	6.11	8.84	222,456
October	4.83	8.09	216,737
November	3.39	6.02	162,176

December	2.69	5.00	142,871
Annual	**5.15**	**7.47**	**2,350,455**
Annual solar radiation - horizontal	MWh/m^2	1.88	
Annual solar radiation - tilted	MWh/m^2	2.73	

Therefore the annual average electricity exported to the grid for the seven Iranian cities is 2,359,315 MW and the city selected for the analysis is Birjand , South Khorasan province in the north east part of Iran.

4.2 Inverter

Power electronics include inverters, which convert DC electricity produced by the PV module into AC electricity used by the grid, and transformers, which step the electricity up to the appropriate voltage. These are often combined into a single integrated device and referred to as the inverter.

Efficiency

The conversion efficiency is a measure of the losses experienced during the conversion from DC to AC. These losses are due to multiple factors: the presence of a transformer and the associated magnetic and copper losses, inverter self-consumption, and losses in the power electronics. Inverters can have a typical European Efficiency of 95% and peak efficiencies of up to 98%. (IFC, 2012). The conversion efficiency is not constant, but depends on the DC power input, the operating voltage, and the weather conditions including ambient temperature and irradiance. The variance in irradiance during a day causes fluctuations in the power output and maximum power point (MPP) of a PV array (table). As a result, the inverter is continuously subjected to different loads, leading to varying efficiency. The voltage at which inverters reach their maximum efficiency is an important design variable, as it allows system planners to optimise system wiring. The inverter efficiency chosen for the analysis was 95 %, coherent with the current technology development.

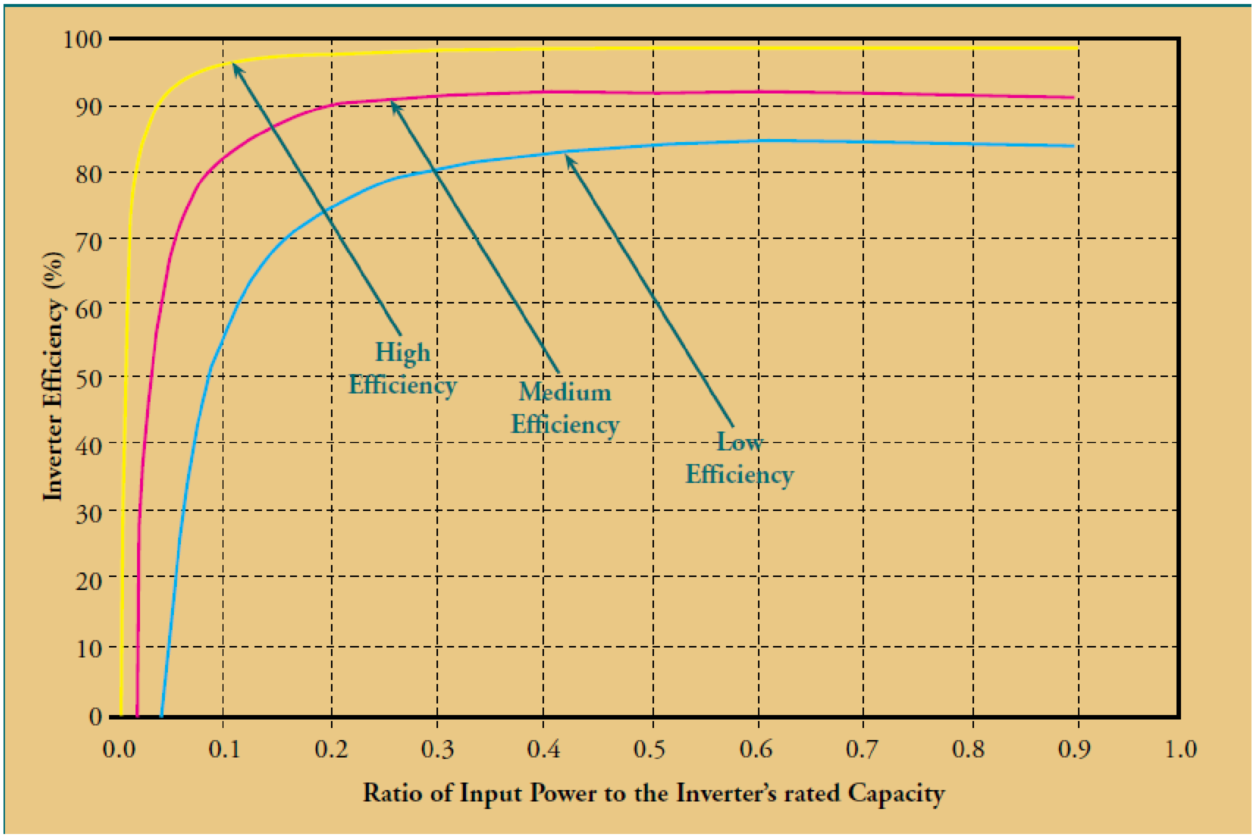


Table: Efficiency Curves of Low, Medium and High Efficiency Inverters as Functions of the Input Power to Inverter Rated Capacity Ratios (Source: Jayanta Deb Mondol, Yigzaw G. Yohanis, Brian Norton. Optimal sizing of array and inverter for grid-connected photovoltaic systems, 2006.)

Sizing and capacity

It is not possible to formulate an optimal inverter sizing strategy that applies in all cases. Project specifics such as the solar resource and module tilt angle play a very important role when choosing a design. While the rule of thumb has been to use an inverter-to-array power ratio less than unity, this is not always the best design approach. For example, this option might lead to a situation where the inverter manages to curtail power spikes not anticipated by irradiance profiles (based on one hour data). Or, it could fail to achieve grid code compliance in cases where reactive power injection to the grid is required. The optimal sizing is, therefore, dependent on the specifics of the plant design. Most plants will have an inverter sizing range within the limits defined by:

0.8<Power Ratio<1.2

Therefore the capacity chosen for the inverter in the analysis was 8000 kW, with 1 % miscellaneous losses.

4.3 Cost Analysis

The costs of a PV power plant are various and variable according to many parameters. They can be divided in three main areas: the initial investment, the annual costs (mainly O&M), and the financing cost

4.3.1 Initial investment

The costs a PV system have witnessed a sharply decreasing trends in this last year, in accordance with the Swanson's law (an observation that the price of solar photovoltaic modules tends to drop 20 percent for every doubling of cumulative shipped volume).

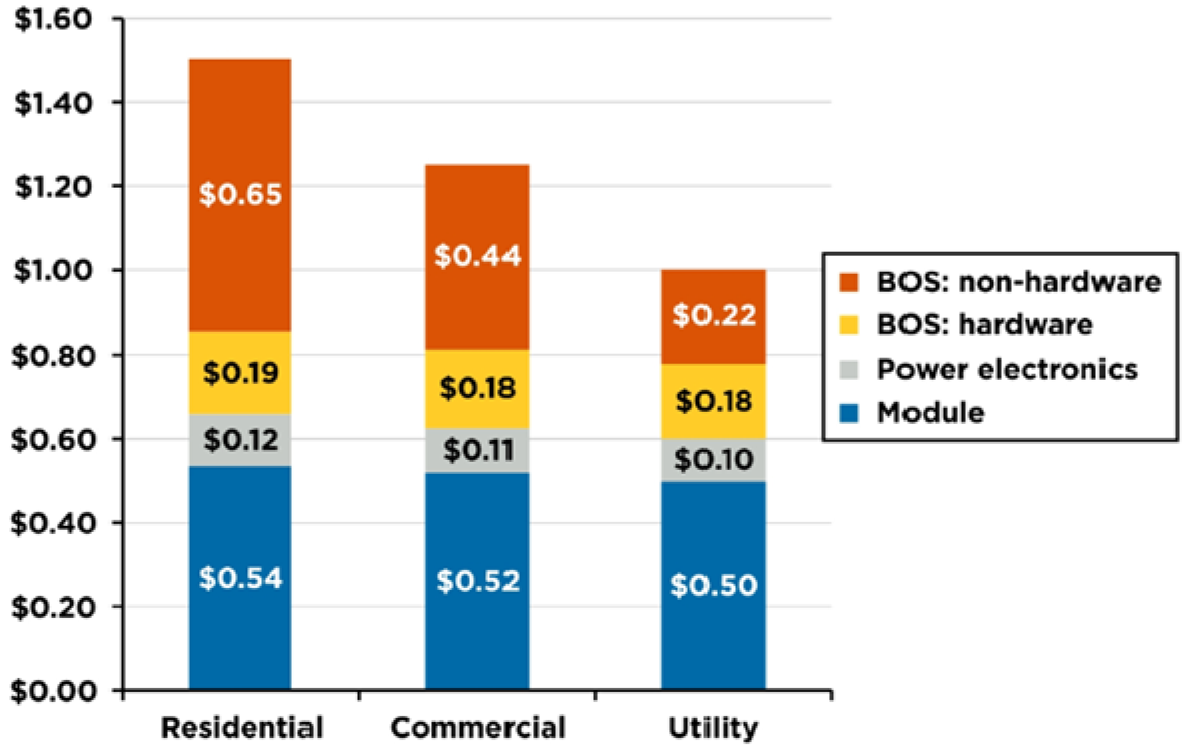
There have been major changes in the underlying costs, industry structure and market prices of solar photovoltaic technology, over the years, and gaining a coherent picture of the shifts occurring across the industry value chain globally is a challenge. This is due to: "the rapidity of cost and price changes, the complexity of the PV supply chain, which involves a large number of manufacturing processes, the balance of system (BOS) and installation costs associated with complete PV systems, the choice of different distribution channels, and differences between regional markets within which PV is being deployed". Further complexities result from the many different policy support initiatives that have been put in place to facilitate photovoltaics commercialisation in various countries. (M Bazilian, I Onyeji, M Liebreich, I MacGill, J Chase, J Shah, D Gielen (2013). "Re-considering the economics of photovoltaic power". *Renewable Energy (53)*.)

The PV industry has seen dramatic drops in module prices since 2008. In late 2011, factory-gate prices for crystalline-silicon photovoltaic modules dropped below the $1.00/W mark. The $1.00/W installed cost, is often regarded in the PV industry as marking the achievement of grid parity for PV. Technological advancements, manufacturing process improvements, and industry re-structuring, mean that further price reductions are likely in coming years.

According to SunShot , an initiative of the Department of Energy in the Unites States, which seeks to make solar energy cost-competitive with other forms of electricity by the end of the decade, the following installed PV system price reductions will be achieved by 2020, relative to benchmarked 2010 installed system prices:

- Residential system prices reduced from $6/W to $1.50/W
- Commercial system prices reduced from $5/W to $1.25/W
- Utility-scale system prices reduced from $4/W to $1.00/W.

Figure X shows the estimated subsystem prices of 2020 SunShot Targets



Therefore in accordance to the decreasing trend of prices, represented by the Swanson's law and DOE's forecast , the initial investment cost was formulated to be 1$/watt, so 1.000.000.000.,00 $ (746.204.000 €) for a 1000 MW power plant, assuming to use average performing PV cells with a 14.1 % efficiency as ground breaking technology is not required due to the enormous potential of the country, both in terms of capacity factor and land availability for the project.

4.3.2 Operation and Maintenance

O&M costs for solar PV are significantly lower than other renewable energy technologies. O&M costs depend on many factors, including the project location and the surrounding environment.
It is difficult to predict the O&M cost over the latter part of the 25 year design life as there are very few large scale solar projects that have been generating for sufficient time to have reached the end of their design life. The modules, which typically comprise over 60% of the total project cost, are generally supplied with performance guarantees for 25 years. However, other project components require routine maintenance and component replacement. Aside from O&M, operational expenditure will include comprehensive insurance, administration costs, salaries and labour wages.
The O&M percentage used in the calculation was the 3% of the initial investment.

4.3.3 Financing costs

The leverage used in the analysis was 50%. The investment was hypnotized to be either 100% in Euro with an interest rate of 8.5% or 100% in Iranian Rial with an interest rate of 20% . The duration of the loan is 10 years. The exchange rate is presumed to be constant over time for the whole duration of the project (IRR 35,264.94). The project was assessed for an analysis period of 20 years. An inflation rate of 16.6% for Iran (Central Bank of Iran, 2014) was used. Therefore the PMT obtained are 56,863,624€ yearly or 3,138,344,257,990,46 Iranian Rials.

4.4 Revenues

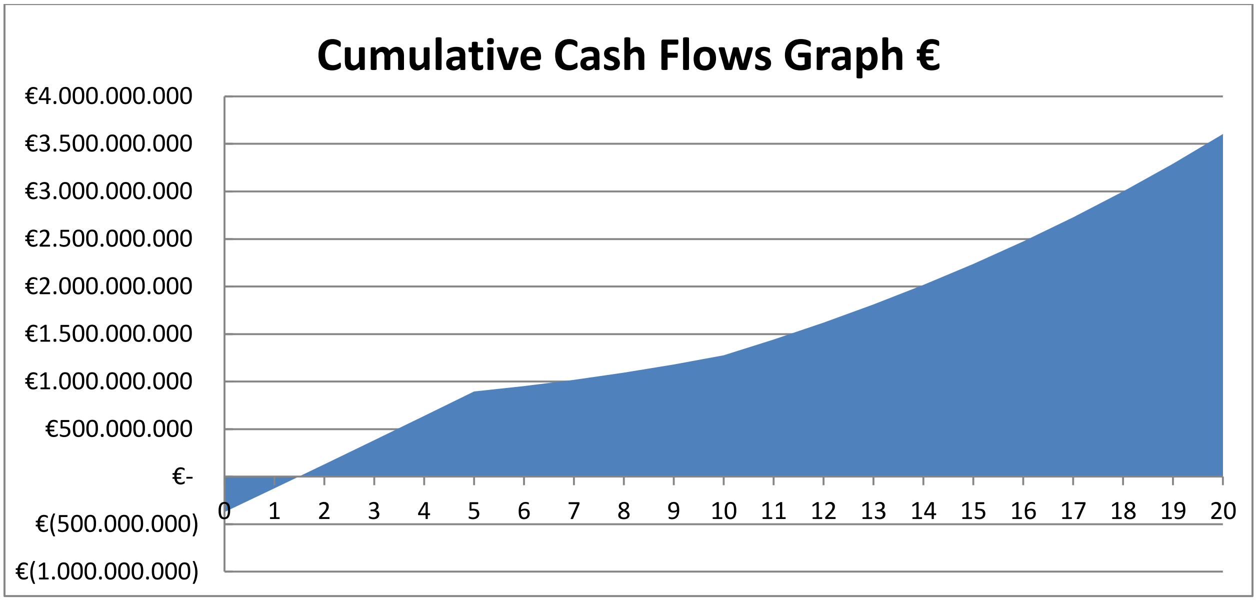
The Feed in Tariff duration may be either 5 years of 8 years with an initial price of 4800 IRR/KW (0,13611 euro) and a percentage annual increase factor *k*, still to be determined more accurately with the Minister of Energy, of 10%. After the duration of the FIT the production cost of electricity from a gas turbine was used to determined the price/kW of 2,821 IRR/Kw (0.08 euro/kwatt).

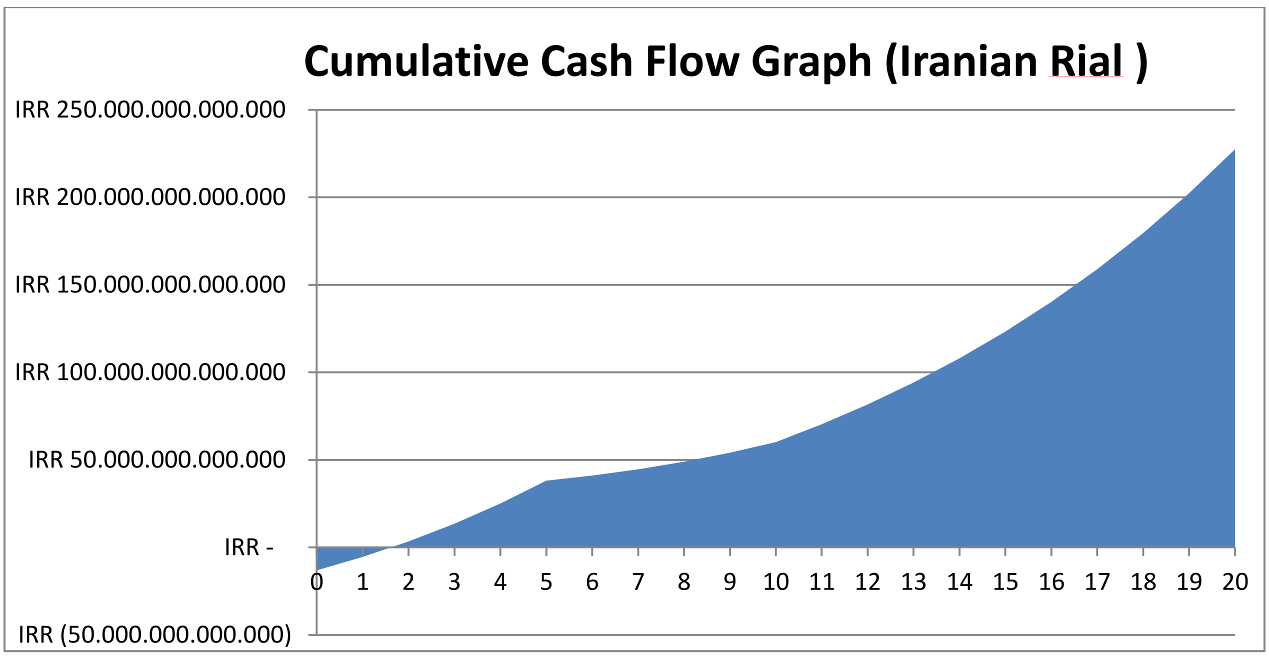
Given the initial hypotheses and an amount of energy exported to the grid of 2,419,379 MWh, the results of the two scenarios where the followings.

Scenario 1: 5 years Feed In Tariff

	€	**Iranian Rial**
Total Benefits	8,533,132,973	300,920,422,318,149
Total Costs	1,762,562,736	73,487,188,808,620
Net Income	6,770,570,236	227,433,233,509,529
PMT	56,863,624	3,138,344,257,990
Percentage annual increase during FIT (K) *{ years 1-5}*	10%	10%
Inflation cost of energy *{ years 6-20}*	10%	10%
IRR	**74%**	**66%**
Payback time	**1.43 year**	**1.62 year**

The data show a return of the investment of 74% in Euro and 66% in Iranian Rial as worst case scenario and a payback time, shown in the tables below, of respectively 1.43 and 1.63 years

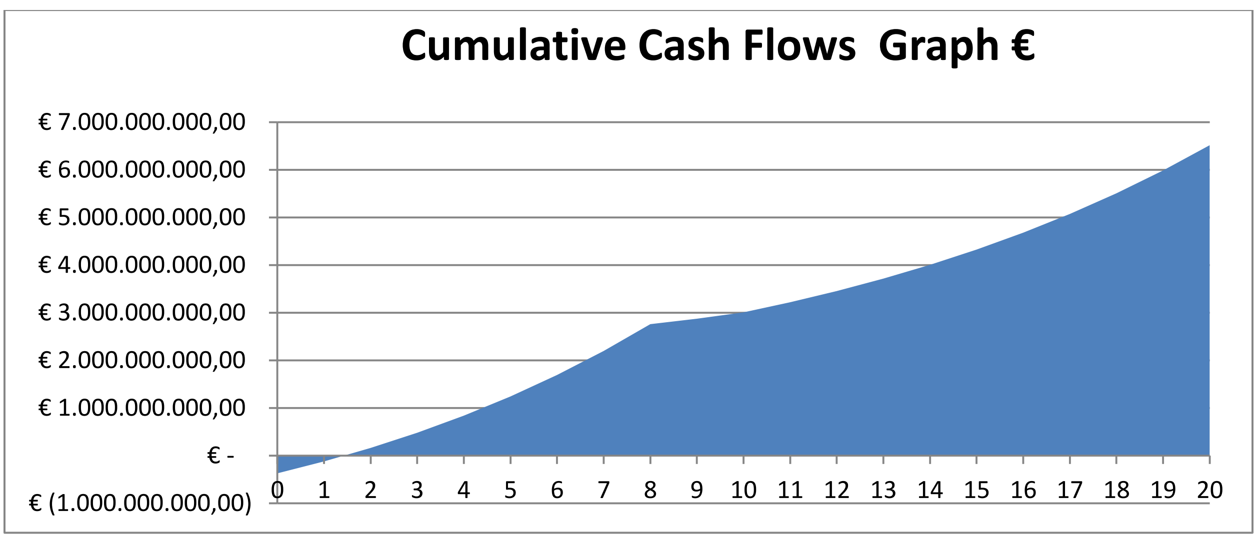


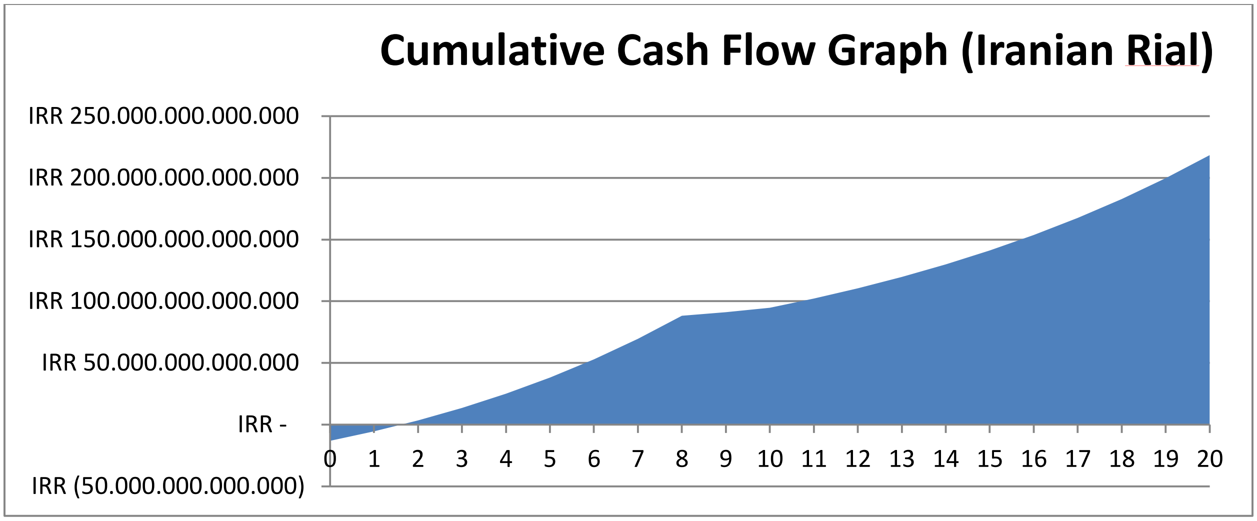


Scenario 2: 8 years Feed In Tariff

	€	**Iranian Rial**
Total Benefits	9,647,951,424	340,234,428,078,486
Total Costs	1,762,562,737	73,487,188,808,620
Net Income	7,885,388,687	266,747,239,269,866
PMT	56,863,624	3,138,344,257,991
Percentage annual increase during FIT (K) *{ years 1-5}*	10%	10%
Inflation cost of energy *{ years 6-20}*	10%	10%
IRR	**79%**	**71%**
Payback time	**1.43 year**	**1.62 year**

The data show a return of the investment of 79% in Euro and 71% in Iranian Rial as worst case scenario and a payback time, shown in the tables below, of respectively 1.43 and 1.63 years




Cumulative Cash Flow Graph (Iranian Rial)
IRR 250.000.000.000.000
IRR 200.000.000.000.000
IRR 150.000.000.000.000
IRR 100.000.000.000.000
IRR 50.000.000.000.000
IRR -
IRR (50.000.000.000.000)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20